MARSHALL
IN-89-CR
114142
P-3

THE ADVANCED X-RAY ASTRONOMICAL FACILITY (AXAF): A POWERFUL NEW TOOL FOR PROBING STELLAR CORONAE

Jeffrey L. Linsky[1]
Joint Institute for Laboratory Astrophysics, University of Colorado and National Bureau of Standards, Boulder, CO 80309-0440

Martin C. Weisskopf
Space Science Laboratory, Marshall Space Flight Center

[1]Staff Member, Quantum Physics Division, National Bureau of Standards.

AXAF, the next major step in NASA's program for X-ray astronomy, is presently in its Phase B definition and design phase and could be launched as early as 1993. The AXAF will be a long duration (>15 years) national observatory with a majority of the observing time set aside for guest investigators. AXAF will have a grazing incidence telescope consisting of six nested Wolter type I paraboloid-hyperboloid mirror pairs ranging in diameter from 0.6 to 1.2 m, and a complement of powerful imaging and spectroscopic instruments. The telescope will have an angular resolution of 0.5 arc-second, collecting area of 1700 cm^2, and significant energy response up to 10 keV. These characteristics and the modern instruments result in AXAF being a far more powerful observatory than HEAO-2 (Einstein) for probing stellar coronae.

The long lifetime of the AXAF will provide the astronomical community with an X-ray observatory capable of following up on the remarkable HEAO-2 (Einstein) results. Even more important, AXAF will be able to extend its own discoveries because of its long lifetime and the prospect of more powerful instruments in the future. This will be the first time that X-ray astronomy will have this capability which is as important as the hardware in assuring the AXAF's scientific success.

The instrumentation that may fly initially at the start of the AXAF mission has been selected, through the peer-review process, and the instrument performance parameters are listed in Table 1. The transmission gratings, the microchannel plate imager (HRC), and the cyrstal spectrometer are more powerful versions of Einstein class instruments. The improvement in sensitivity results from the superior performance of the AXAF telescope and from the improvements in technology in the past decade. The effective areas of the grating spectrometers are typically more than a factor of 50 larger than their Einstein counterparts. The CCD imager and the X-ray quantum calorimeter represent recent advances in X-ray detector technology. The former extends high efficiency, high resolution imaging with solid state energy resolution to the highest AXAF energies and also serves as the most promising detector for the high energy transmission gratings. The calorimeter, currently in development, represents a major step forward in high efficiency, high energy resolution nondispersive spectroscopy.

The overall improvement in sensitivity that these instruments, together with the AXAF telescope, bring to X-ray astronomy is truly remarkable. For example, Einstein had observed approximately 500 solar-type stars, whereas the AXAF could

Table 1. Initial AXAF instruments chosen for development and their anticipated performance.

Instrument	Principal investigator (institution)	Energy res. $E/\Delta E$ at 1 keV	Energy range (keV)	Effective area (cm^2) at 1 keV	Angular res. (arcsecs)	Min. detectable flux in 10^4 s (ergs cm^{-2} s^{-1})
High resolution camera (HRC)	S. Murray (SAO)	$\gtrsim 1$	0.1-8	500	0.5	2.4×10^{-14}
AXAF CCD imaging spectrometer (ACIS)	G. Garmire (Penn State)	7	0.1-10	1000	0.5	6×10^{-15}
Si (Li) spectrometer	S. Holt (GSFC)	>10	0.3-10	1000	60	6×10^{-15}
Quantum calorimeter (QC)	S. Holt (GSFC)	>100	0.1-10	1000	20	1.6×10^{-15}
Trans. grating spectr. (TGS)	A. Brinkman (Utrecht)	~200	0.1-8	45	---	2×10^{-14}
Trans. grating spectr. (TGS)	C. Canizares (MIT)	300-1000	0.4-8	140-300	---	3×10^{-15}
Bragg crystal spectr. (BCS)	C. Canizares (MIT)	2000	0.14-8	11f	---	1×10^{-13}

f = fraction of time scanning a spectral feature.

observe in a few months all of the more than 6000 stars accessible (but not observed) by *Einstein*. The total number of stars accessible to AXAF is, of course, vastly larger, and the available volume of space for sampling will increase by a factor of a thousand.

The *Einstein* has had a profound impact on stellar astronomy because it replaced a picture of stellar coronae based on a handful of detections with a picture based on detections of X-rays from nearly every type of star (cf. Vaiana *et al.* 1981; Linsky 1982). The only region of the HR diagram from which no stellar X-rays have yet been detected is that containing the K-M giants and supergiants (Ayres *et al.* 1981). *Einstein* also observed a large spread (a factor of 300) in X-ray luminosity of late-type stars of the same spectral type and luminosity class, which indicates that effective temperature and gravity are not the main parameters determining the properties of stellar coronae. Instead, strong, closed magnetic fields confine coronal structures (Rosner, *et al.* 1978), and they likely determine the heating rate and control the energy balance. Empirical correlations of X-ray luminosity with rotation rate, age, convective zone depth, and Rossby number support the all-pervasive role of dynamo-amplified magnetic fields. By observing a wide range of stars and coronal parameters, AXAF should provide insight into the detailed mechanisms for coronal heating which are uncertain even for the Sun.

While the Einstein has given us valuable information about the types of stars that have hot coronae and the ranges of X-ray luminosity for each spectral-luminosity class, we still know very little about the important physical properties of these coronae. Einstein lacked the sensitivity and the spectral resolution to measure temperatures accurately and to measure coronal densities and flow velocities. Thus, we can now only speculate concerning the geometry, heating rates, acceleration mechanisms, and causes for coronal variability and dynamic phenomena such as flares. The AXAF will permit a quantum leap in observational capability to measure the important coronal plasma parameters. Some important questions that AXAF should be able to attack include:

1) What is the range of coronal temperatures that occurs in coronal magnetic loop structures? Moderate resolution spectroscopy is needed to determine whether the temperature depends on spectral type or rotational velocity among the cool dwarfs.

2) What are the evolutionary time scales of coronal loops and active regions, and what are the properties of stellar magnetic cycles and dynamos?

3) What are the densities in flares on different types of stars? X-ray spectroscopy with high resolution and sensitivity is needed to measure the flux ratios of X-ray lines that are density sensitive for $n_e \gtrsim 10^{12}$.

4) Do X-ray luminous active dwarfs have hot winds and low mass loss rates like the Sun? High resolution spectroscopy is needed to search for Doppler-shifted X-ray lines.

5) What are the fundamental differences between the coronae of young and old dwarf stars? Are the differences primarily in the fraction of the volume filled with loops, the loop lengths, densities, temperatures, or total heating rates?

6) What are the variations of temperature, electron density, X-ray luminosity, and emitting volume as a function of time during flares in M dwarf stars? High time resolution demands the high throughput of AXAF.

7) What are the turbulent and systematic mass motions during flares, and do these motions play an important role in the flare energy balance? Also, are flares cooled primarily by radiation, conduction, or expansion?

This work is supported by a NASA grant to the National Bureau of Standards.

REFERENCES

Ayres, T. R., Linsky, J. L., Vaiana, G. S., Golub, L., and Rosner, R. 1981, Ap. J., 250, 293.

Linsky, J. L. 1982, in X-Ray Astronomy in the 1980's, edited by S. S. Holt, NASA Technical Memorandum 83848, p. 13.

Rosner, R., Tucker, W. H., and Vaiana, G. S. 1978, Ap. J., 220, 643.

Vaiana, G. S., et al. 1981, Ap. J., 245, 163.